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ABSTRACT

Issues and recommendations concerning a national policy for undergraduate science education are examined from the perspectives of the National Science Foundation (NSF), the corporate sector, and the National Higher Education Associations' Task Force. In "The Federal Role in Undergraduate Science and Engineering Education," NSF Director Erich Block considers economic challenges that affect research and education and tells of undergraduate activities and programs that NSF has created in response to these challenges. In "Some Personal Observations from the Private Sector," Hewlett-Packard scientist and manager James W. Serum discusses interest in science careers, the research focus of undergraduate institutions, and the shortage of instrumentation and equipment for scientific research and education. Finally, the Task Force report, "National Priorities for Undergraduate Science and Engineering Education," recommends that NSF: (1) start a challenge grant program to improve undergraduate science and engineering education; (2) start some consortia as centers of instructional excellence in undergraduate science, engineering, and technical programs; (3) expand the college science instrumentation program; and (4) expand support for undergraduate research activities. (SW)

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ACE SPECIAL REPORT

Towards a National Policy for Undergraduate Science Education:

with the Recommendations of The National Higher Education Associations' Task Force

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Foreword

The National Science Foundation's role in supporting undergraduate science and engineering education is under review in the Congress and the Executive branch. The results of this scrutiny will have important implications for the nation, as well as for undergraduate science programs at America's colleges and universities.

To assist national policymakers by identifying the community's priorities for strengthening NSF programs in undergraduate science education, the American Council on Education recently convened a special task force of presidents appointed by major national associations and chaired by Philip Jordan, President of Kenyon College and Chair of the ACE Board of Directors. ACE also featured the federal role in undergraduate science education as the subject of a plenary session at its 1985 annual meeting.

The results of these efforts are presented in this booklet, which includes the papers delivered at the plenary session examining the subject from the perspectives of the National Science Foundation, represented by Erich Bloch, Director of the NSF; the business community, in a report by James W. Serum, Hewlett-Packard Company; and, finally, the report of the associations' task force outlining the priorities of the colleges. It is encouraging to note the extent of agreement among the three presentations.

We are publishing these important papers to inform the growing public discussion of the issue. Our thanks to the Teagle Foundation for making their publication possible.

Robert H. Atwell
President
American Council on Education

Introduction

by Phillip Jordan

President, Kenyon College

Today, the need for a national policy for undergraduate science education is receiving increasing attention in Washington and on campuses across the land. The subject is tied to a developing national strategy to rebuild our human and capital resources for basic science and research. This strategy recognizes the need to strengthen American scientific and technological capacities, to enhance industrial and economic competitiveness, and to strengthen the national defense.

Undergraduate science education is also important on the agenda of general educational reform in the quality of undergraduate education. To strengthen education in science, engineering, and technology at the undergraduate level in all of its various settings is to address the quality issue in one area of a larger enterprise.

While the role of public policy in general, and the role of the National Science Foundation in particular, is critical, the present deficiences cannot be cured by federal initiative alone. The remedy also requires the commitment and cooperation of campuses and, among other private elements, the corporate community. The federal role must be sharply focused for maximum effect with scarce resources, and federal support should, where possible, be leveraged to attract significant supplements from non-federal sources.

The country's problems in undergraduate science education include the declining proportion of American undergraduate students who enter college as intended science majors, a declining proportion of undergraduates who receive science baccalaureates from many institutions, including some of our highest rated universities, declining numbers of the ablest students who go on to doctoral training in science and engineering, and, especially, the growing unmet need for replacement and upgrading of scientific instructional equipment and materials.

As an undergraduate philosopher, a professional historian, and a liberal arts president, I am deeply interested in the topic as an educator

who is not himself a scientist. This fall I became more knowledgeable as I chaired a task force of other presidents, scientists or engineers in background, to prepare a report for the National Science Board on national priorities in undergraduate science education. This report was encouraged and requested by the National Science Foundation Director, Erich Bloch, to assist the NSB in its study of undergraduate science, engineering, and education needs.

In Chapter One, Director Bloch addresses our Task Force's priorities in a most gratifying manner. He also presents a great deal of information about the efforts the NSF has made, and is continuing to make, to meet undergraduate needs.

Dr. James W. Serum of the Hewlett-Packard Company, in Chapter Two, shares his observations on the current state of undergraduate science and engineering education from a corporate perspective. His views reinforce the urgency in meeting the needs for a national policy for undergraduate science and engineering education that the task force has set forth in its report. He also offers some interesting solutions to the current problems plaguing science and engineering education.

The booklet concludes with the report of the national higher education associations task force, which represented a wide variety of institutions from two-year colleges to research universities. I would like to remind readers that, although the task force rapidly reached a consensus about the pressing needs in the undergraduate area and the priorities for addressing them, the recommendations were not unanimous: there were some differences in perspectives on certain points of view. Nevertheless, members of the task force agreed on the premises about national need, about the importance of human resource development, and about the continuous quality of education from schools through colleges to graduate training in the preparation of American men and women of science and engineering.

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Chapter One

The Federal Role in Undergraduate Science and Engineering Education

Erich Bloch

Director, National Science Foundation

To begin my discussion of undergraduate institutions and their efforts to strengthen education in science and research, I would like to comment on the economic challenge facing our nation today, and its relationship to research and education.

The most striking and pervasive change of the 1980s—one that is fundamental and irreversible—is the shift to a global economy. The new worldwide economy features sharper international competition, especially in areas of technology where the United States has been pre-eminent since World War II. I need only mention the challenges of the last few years to the nation's automotive industry, its consumer electronics industry, and its semiconductor industry. The success of the Japanese in manufacturing and marketing has had rapid and sweeping effects on our industrial base.

Japan is not the only new competitor for world leadership in certain technologies. South Korea and other Pacific rim nations are following right behind Japan. Other countries, such as Brazil and India, also are aspiring to major positions in specific technology by the end of the century—and they have the potential to achieve them.

As the report of the President's Commission on Industrial Competitiveness pointed out earlier this year, other nations have considerable advantages in world competition that are not easy for us to overcome.

Cheaper labor and lower interest rates are two of their strongest advantages. In addition, some countries have the added advantage of protecting their industries from foreign competition.

The United States maintains two clear advantages in international competition: First, the flow of fresh ideas and discoveries from researchers in universities, companies, and government agencies; second, our large, diverse, flexible pool of human resources. Through these means entrepreneurs can capitalize on discoveries, create new technologies, and market them, thus serving both the established and growing companies, the government, and academia.

The only way that we can continue to stay ahead of other countries is to keep new ideas flowing through research and to have the best technically-trained, most inventive and adaptable workforce of any nation. That is the fundamental reason why a good education in science, mathematics, and technological subjects is vital—not only for undergraduates, but throughout the educational system, beginning in the primary grades.

The nation as a whole must step up its efforts to attract and educate those who will be critical to our technological future—the thousands of scientists and engineers for research in every field, and the hundreds of thousands of technicians and other support people, who are necessary for our society to function.

The nation must also strengthen science education because America will always have to deal with complex environmental, economic, and ethical issues that require a fair degree of understanding of the sciences involved. Such difficult public issues as toxic wastes, nuclear winter, and acid rain will remain to be dealt with in the decades to come. No doubt they will be joined by new issues arising from advances in biotechnology and medicine, and from still unknown discoveries in many other fields.

The nation depends upon its undergraduate colleges to provide a high quality education in science, mathematics, and technical subjects:

- To the relatively small number who will go on to pursue the research doctorate;
- To the larger number who will become teachers, engineers, or the technical specialists in industry;
- And to the many others who will become leaders of industry, government, universities, media, and public interest groups.

It is now particularly necessary to increase the number of persons who will go on to an advanced degree in science or engineering. The nation is short of advanced degreed engineers to staff our faculties and our government and industry laboratories—yet our production of Ph.D. graduate engineers is not increasing.

This is true not only of engineers: the production of doctorates in the physical sciences fell off sharply in the 1970s and has not recovered; and the number of new Ph.D.'s each year in mathematics fell by about 30 percent from 1974 to 1984. Moreover, a high proportion of recent Ph.D. graduates are not from the United States. Foreign nationals now receive over half of U.S. Ph.D. degrees in engineering, up from about a quarter twenty years ago. In fact, almost all recent growth in graduate science enrollments has come from foreign students.

It is notable that sixty per cent of these foreign nationals are staying here and joining our workforce. They are a vital element in academia, industry, and the government, but I think we must clearly understand that in many fields we are developing an overdependency on foreign students for teaching, research, and the general workforce. It is also entirely possible that this source of talent could be removed with very little advance notice and for reasons that are entirely beyond the control of science and education policy-makers—or of our government.

We need to make sure that pursuing the Ph.D. track in the physical sciences and engineering is not becoming an un-American activity!

To complicate matters, the pool of potential students from U.S. schools will become smaller. Demographic projections show the number of 18–24 year olds declining by about 20 percent over the next decade. Unless a much higher proportion of them become interested in pursuing a major in science or engineering, enrollments in these fields will decrease greatly at the undergraduate level in a few years.

Important policy issues for undergraduate science and engineering education are: How can we attract a much higher proportion of freshmen from U.S. high schools to programs in science, mathematics, and engineering; and how can we provide them with a high quality education throughout their undergraduate years? A related policy issue is: how can we induce more students from under-represented groups of women and minorities to become scientists and engineers?

Interest in scientific subjects usually begins long before students enter college. Studies have shown repeatedly that most students who go on to become scientists or engineers develop their interests, and an idea of their own competence, during elementary, middle, and high school years. Perhaps it is more accurate to reverse the idea and say that most students are "turned off" to science in those early years because of a poor instructor or because they come to believe that the subject is just too difficult or remote for them.

Undergraduate institutions, then, must strive to develop more and better links with high schools and junior high schools. In addition to continuing education or summer programs for teachers, perhaps colleges and universities could offer help to them in other ways—opening up lab facilities for a tour by tenth-graders; or asking some of the

better science teachers to spend one day a semester visiting some ninth-grade classes.

Once students enter college, what can be done to sustain their interest and build competence? I have observed, and been told by educators and students alike, that the best way is to offer some genuinely interesting laboratory courses in freshman and sophomore years. Today, some schools have watered down lab courses or substituted non-lab courses, because they lack adequate facilities or instructors, or because many students consider lab courses too difficult.

Nevertheless, there will never be a substitute for "hands-on" laboratory experience in a small group taught by a competent, interested instructor. In short, attracting more of our best people to science and engineering and providing them with a vigorous education is a priority for our country.

In response to these challenges, the National Science Foundation has created several activities and programs in undergraduate education. To begin modernizing laboratories, the Foundation has developed a new program to supply instructional equipment to colleges. The NSF made more than five million dollars in awards in 1985. This is a fair start, but the program is in such high demand that we hope to raise that funding level in future years.

Once students enter their third or fourth years, the best way to prepare them to undertake graduate work is by increasing opportunities to participate in research activities. NSF recognizes the importance of research at undergraduate institutions, and the link to developing scientific and technical talent, through our research in predominantly undergraduate institutions program (RUI). The NSF reinforced that recognition two years ago by establishing a special, across-the-board effort to increase participation and support of undergraduate institutions in our research programs—without compromising the high standard of competitive review that is the Foundation's hallmark.

Most of the Foundation's research support divisions are responsible for seeing to the vitality of a particular discipline. Rather than change this structure, we devised a way to manage, track, and fund proposals from undergraduate institutions across the existing organization.

As a result, in fiscal 1984, we supported about $41 million of research awards to predominantly undergraduate institutions, an increase of 40 percent over the $29 million made in fiscal 1983, and well above our target. In fiscal 1985, just completed in September, the total was $47 million, a further increase of roughly 15 percent over 1984.

It should be noted that these percentage increases are significantly higher than the increases in NSF's overall budgets for these three years, and we hope to raise the amounts for this current fiscal year.

I should add that about a third of proposals from undergraduate institutions are funded. That figure compares favorably with the proportion for similar single-investigator projects from the major universities.

Although the major research institutions still receive the majority of NSF awards, the substantial funding increases just mentioned demonstrate that much good research can be done outside the graduate research universities—and that NSF recognizes that fact.

Understanding that good research ideas can come from all sectors, we intend to keep the system open to proposals from the whole range and breadth of academic institutions in every part of the nation. We will continue to encourage researchers at undergraduate institutions to apply for funds.

We have also made an important effort of a different sort—the opportunity for an undergraduate instructor to join an existing NSF-supported project in any field of research and at any institution, simply by requesting, or having the principal investigator request, that a faculty person from an undergraduate institution be added to the grant. Basically, all it takes to apply for these research opportunity awards (ROA's) is a brief letter to the NSF program outlining the researcher's interest, qualifications, and projected expenses. If it is agreeable to the principal investigator and the institution, we will then supplement the grant budget without extensive review. This is a good way for faculty to refresh their experience with some forefront research work, and to prepare themselves to submit a proposal of their own.

The NSF continues to encourage undergraduate faculty to serve on our review panels and advisory committees and to seek positions on our staff as "rotator" program officers, who serve one or two years before returning to their colleges. Both types of service are excellent ways to learn more about how the system operates, to get a clearer picture of where the research frontiers are, and to influence the programmatic aspects of NSF. To date, the number of reviewers and panelists from undergraduate institutions is relatively small, but it has nearly doubled since I have been Director and my staff has been instructed to increase the undergraduate presence wherever possible.

The efforts I have just described—stepping up support of research awards, adding researchers to projects, and increasing representation on our panels, committees, and staff—demonstrate the foundation's concern for undergraduate institutions. These efforts further the NSF's principal objective of generating the scientific and engineering talent that the nation will need to sustain its future competitiveness.

We are convinced that the most effective way to achieve that

objective is for the Foundation to support research, and through research enhance and foster the education of everyone who comes in contact with it—and to make sure that the system remains an open and fair one that accepts proposals and ideas from every source.

The foundation is right now actively and carefully considering the state of undergraduate science and engineering education. A special committee of the National Science Board (chaired by Dr. Homer Neal, provost of the State University of New York at Stony Brook) is conducting public hearings on this topic. Two hearings have been completed, and two more are planned. I should point out that it is very unusual for the Board to hold extensive public hearings, which by itself demonstrates the importance that we are giving to this subject.

A variety of leaders from academic institutions, industry, and government have appeared as witnesses, or are scheduled to appear. In addition, the committee has sought and received a number of letters and reports from organizations and individuals. The committee intends to present its recommendations to the full Science Board in January. I cannot predict precisely what those recommendations will be —much less how they will fit into the fiscal 1987 budget when it goes to the Congress in January—but I do want to assure you that we are listening and learning, and paying attention to the issues.

We appreciate the role the American Council on Education and the other associations and societies are playing in this process. I would like to assure you that, first, your Priority One, undergraduate instruction equipment and materials, is in line with our own thinking, and we also concur that increases in this area are required.

Second, your proposal to expand support across the directorates is in line with the implementation I described of the NSF's undergraduate institutions program and the linkage between research and education in all NSF's research activities.

Third, I'd like to thank the report writers for their confidence in NSF in asking us to increase our leadership; but we are not the only federal source for support of undergraduate education. NSF cannot be, and the federal government cannot be, the only player in this arena.

With regard to your assessment of the bugetary level, let me underline a point President Fred Starr of Oberlin College made at our hearing: that increased support for undergraduate programs should not be made at the expense of the other research and education activities of NSF. I agree.

The next three years will be difficult budget years. We must look at the entire $53 billion federal R&D budget to find any money for new initiatives or for added emphasis in existing areas, if we want to better

basic research and infrastructure support. Incremental dollars will not be available.

The cause for reallocation is compelling. For most of the post-war period the primary rationale for federal support of research has been the support of specific government missions. In the early years following the war this meant that most research support in the physical sciences came from the Department of Defense and the Atomic Energy Commission. In more recent years, other agencies have been more involved.

The trouble with a system that relies primarily on the mission agencies for support is that it introduces a systematic bias against basic research. Except for the Sputnik era in the 1960s, the federal government has not done a very good job of supporting the overall science and engineering base—the researchers, equipment, and facilities in universities and colleges that we depend on for education and basic research.

In the last four years, the federal government has started to renew its commitment to the science and engineering base. In the civilian part of the federal R&D budget, development has dropped from the largest part of the R&D effort to the smallest, and basic research has risen to become the largest component. This is an extremely important change.

On the defense side, however, basic research is a small part of the effort. And since defense is an increasingly large part of the federal R&D effort, the overall effect in the last year or two has actually been a reduction in the proportion of the federal R&D dollar that goes to basic research.

We need to go much further than we have in reallocating R&D resources from development to support of the science and engineering base. The easiest way, of course, would be simply to add funds to the total. But that is not realistic in today's budget climate.

What is necessary is that we recognize that the federal government can do some things well, and that support of the science and engineering base is one of them. We must also recognize that it does some other things not well at all—including making decisions about technologies that should be developed for commercial reasons.

If we are sufficiently tough-minded about cutting out the latter—still a significant fraction of the budget—then we should have available the resources to substantially increase the support of basic research and the science and engineering base. I would like to see support for that base increased at an annual rate of ten percent or so for the next ten years. Unless we make this tradeoff our research and education efforts will not be sufficient to stay ahead of the economic competition.

There is no question of the importance to the nation of strong science

and engineering education programs throughout all levels of colleges and universities, including those that principally offer the baccalaureate degree. All parties—the colleges themselves, industrial firms, state governments, and the federal government—must contribute to keep these institutions productive. I emphasize the notion of involving all parties in partnerships and cooperative arrangements, because the federal government and NSF is limited in what it can do—or should do.

State governments have a particular interest in strengthening their state and private institutions at every level. There is a considerable—and, I believe, healthy—competition among the states for high-tech industry. Many state governments realize the importance of a well-educated technological workforce for their economies. Tennessee and New Jersey, for example, have recently made significant investments in research and education.

Companies have a very strong role to play here as well. More of them than ever are developing partnerships with academic institutions. They benefit very directly, not only from the ideas that flow in both directions, but from having access to well-educated workers. I would urge private sector representatives to learn more about, and consider entering into, the kinds of partnership arrangements that undergraduate institutions are prepared to offer.

Chapter Two

Some Personal Observations from the Private Sector

James W. Serum, Ph.D.

Hewlett-Packard Company

Speaking as a scientist, an alumnus of a small liberal arts college, and a manager in industry, I would like to offer some of my personal observations about the current conditions of science education in America. My views have evolved during the past several years from frequent interactions with faculty and administration at both research and undergraduate institutions.

My first observation is that "science" is not perceived as the exciting career path for young people that it was twenty years ago when I was in school. I believe that this perception lies at the very heart of the challenge we face in American science education.

According to reports, the number of scientists and engineers engaged in active research in the United States has increased only 25 percent from 1965 to 1979, while in Japan the corresponding increase was 139 percent, and in the Soviet Union the number increased by 140 percent. Furthermore, the actual number of college freshmen indicating an interest in science has dropped by 33 percent from 1975 to 1984. From an industrial point of view, these statistics become critical, because the growth of a company begins to be limited simply by the inability to get good scientists. Although society in general has taken a less than enthusiastic position toward science in recent years due to the strong focus on our environmental problems, I believe that a significant part of the decline stems from the approach we take in exposing our young people to opportunities in science. Today, a young person becomes highly adept with a computer at a very early age, yet I need to ask how extensively we utilize computers as part of the curriculum

in first year science programs. Instrumentation and electronics have become a fundamental part of chemistry, yet, as I visit campuses, this equipment is often reserved for advanced course work, and only science majors are "privileged" to use it.

Educators should be aggressive, not only in the quality of the science taught to those who major in science, but in developing a curriculum of entry level sciences that stimulates many more of our young people to turn to science as a career. We must endeavor to make science the "fun" and exciting opportunity that it was in the 60s.

My second observation concerns the research focus at the undergraduate institution. As emphasis on research activities is increased, there is a growing tendency to emulate the graduate research institution. I suspect this is subtly driven by the competition to get research funding; nevertheless, I would strongly urge undergraduate institutions not to lose sight of their primary mission and unique capability as educators.

At an undergraduate institution, the primary role must be the education of the student. Although research is vitally important, it should be a "tool" to provide the stimulation and breadth of exposure for the student to a research environment. The faculty should not attempt to push the frontiers of science forward in competition with graduate research institutions. Each institution has its role and both are critical to our educational process.

Hope College has excelled in undergraduate research for many years and I personally place great value on the undergraduate education I received there; however, the greatest contribution came from the role models provided by the faculty through small classes and the opportunity for me to explore "science" side by side with a faculty member in the laboratory.

This leads to my next observation, which is closely related to the second. I have encountered two statistics which, when taken together, are particularly noteworthy. One is gratifying and the other is alarming. First, if one examines all Ph.D.s awarded in chemistry in the United States between 1920 and 1980, about 45 percent of recipients earned a baccalaureate degree from a predominantly undergraduate institution. One must certainly conclude that the undergraduate educational institution is vital to the success of science education in America. The related and alarming statistic comes from the recently published "Oberlin Report," which states that about one percent of the total money awarded by the NSF to the academic sector in 1982 went to fund science at undergraduate institutions. I must add that I do not consider this solely due to NSF's established priorities, but also to the general lack of focus in the United States on undergraduate

education and to a lack of understanding of the importance of the role of research in the undergraduate educational process.

I am sympathetic to the dilemma faced by NSF and other granting institutions, as I participate in the review process for equipment grants for our Hewlett-Packard Foundation. We receive about ten times more requests than we are able to fund. Many of the proposals that do not get approval are actually good proposals: there is simply a much greater need than there is funding. The real problem should not be seen as the competition of the undergraduate institution with the research institution, because both face a crisis of funding. The real challenge is that of raising the overall level of funding for science research and education in America.

A final observation relates to the critical shortage of instrumentation and equipment for scientific research and education. Again, the crisis exists at both our graduate and undergraduate institutions. I focus here on the chemistry departments because I am most familiar with them, but I believe it applies equally to the other disciplines. The recent Pimentel Report on "Opportunities in Chemistry" recognizes the shortage of instrumentation as one of its most critical challenges for future chemical research. Last year I participated in a task force for the National Academy of Sciences, which met to discuss the future of analytical chemistry. Again, the primary focus was the critical shortage of instrumentation. A recent report by a task force for the American Council on Education, headed by Phil Jordan, echoes this same theme. The report states: "In our view, the primary need of undergraduate institutions is instructional scientific equipment and materials. . . ."

When I visit schools, I frequently see equipment that has been obsolete for 20 years being used to demonstrate a scientific principle. I wonder how we can stimulate our young people to pursue careers in science when we expose them to this kind of instrumentation at school, and then have them go home to play with a state-of-the-art personal computer. The personal computer of today may well be the Gilbert chemistry set of yesterday, a "tool" which I'm sure stimulated many of us toward our own careers in science.

Of course, solving this instrument shortage problem is not the singular responsibility of the NSF, but rather the responsibility of all of us. . . . government, academic institutions, and industry. The solution, I'm equally certain, lies in a collective, cooperative effort by all of these groups working together.

We might begin this cooperative effort to solve the problem in the following areas. We need to find a mechanism by which the NSF can fund the qualified research, with industry cooperatively setting aside

additional funds for equipment and supplies to those NSF recipients. During the past few years I have seen a growing dilemma within NSF to be able to provide funding for everything including personnel, supplies, and equipment.

A relationship like this is no different than a marriage or strong personal relationship. In order for it to be successful, it must be built upon a strong foundation of common goals and beliefs. All participants must feel as if they gain something from the relationship, and each must be prepared to give more than it receives. I believe we have these common goals, and that we can all work together to meet this challenge.

I have recently learned that the NSF is currently working toward this objective. I have met with the chairman of this project, and we are exploring ways in which we can work together for the greatest impact on our science education program.

The instrumentation crisis also needs to be addressed through greater participation of industry in equipment grants. This spring, the Council on Financial Aid to Education sponsored a seminar which was hosted by Hewlett-Packard to broaden the knowledge of establishing corporate equipment grant programs. I have offered, on behalf of Hewlett-Packard, to hold another seminar for chemistry instrument manufacturers, and the Council on Undergraduate Research has agreed to sponsor it.

Finally, I'd like to return to my initial remarks on the challenge of making science education a stimulating experience so that we may attract more young people to the exciting part of the world we scientists live in every day.

My company has enjoyed a reputation over many years for innovation and the ability to attract and retain outstanding professionals. I'm sure there are a number of complex reasons why this is true, but I fundamentally believe it is the result of the philosophy provided by our founders, Bill Hewlett and Dave Packard. A couple of years ago I attended an R&D managers' conference where Bill Hewlett spoke. During a subsequent discussion, he was asked what advice he would give to us as we looked ahead during the next 20 years as HP managers. His response: "Keep HP a fun place to work, and encourage creativity to flow and be recognized."

I believe that our science education challenge is similar. We need to work together to make science education a "fun" experience, where we recognize and encourage the creativity of our young people. If we truly accomplish this, we can again experience the "golden years" that science has seen in the past.

Chapter Three

National Priorities for Undergraduate Science and Engineering Education

a report by

The National Higher Education Associations' Task Force

This report deals with an essential element of the developing national strategy to rebuild our human and capital resources for basic science and research. The strategy is evolving out of growing recognition of the need to strengthen America's scientific and technological capacities to increase industrial and economic competitiveness and to strengthen the national defense.

National policies for long-term investment in research and education to address this complex set of problems must be fashioned with a clear understanding of the critical role of undergraduate science and engineering education. The process of science, engineering, and technical education and of the education of scientists, engineers, and technicians is continuous. The undergraduate years are a crucial phase in that process. They are the years when qualified students learn basic scientific concepts in sequential study and weigh career choices as professional engineers, scientists, and teachers.

The federal concern with the production of trained scientific and engineering manpower thus requires direct and appropriate investment in undergraduate education—research and instrumentation and teaching programs—in all its settings, whether at two-year or four-year institutions or in undergraduate programs at research universities. Undergraduate institutions are a primary concern of this report because they have historically attracted high-ability science students, produced a disporportionately large number of science and engineering bacca-

laureates, and served as primary feeder institutions for top graduate-level programs. Many other undergraduate institutions have a tradition of strong teaching in the physical sciences and engineering, and the potential to increase significantly their production of scientists, engineers, and technicians. Community, junior, and technical colleges have special missions and special competence in training and instruction in new technologies, and also serve as important feeder schools for baccalaureate and graduate programs.

Recently there have been encouraging signs that the role of undergraduate science and engineering education is gaining renewed recognition. In May, NSF's policymaking National Science Board appointed a Task Committee on Undergraduate Science and Engineering Education to review the agency's programs in this area. In June an influential conference at Oberlin College was held to discuss a report on "The Future of Science at Liberal Arts Colleges." In July, the House-passed HUD-Independent Agencies appropriations bill directed NSF to "look for opportunities to expand undergraduate support and . . . report by March 1, 1986, on the Foundation's assessment of needs in the undergraduate area and the progress toward the development of programs to meet these needs."

This report outlines the priorities of the higher education community to assist NSB's Task Committee in building a carefully-focused, leveraged program of NSF leadership and support for undergraduate science, engineering, and technical education. We urge that such a program be implemented as promptly as fiscal realities permit, emphasizing the importance of sustained funding and careful evaluation of program impacts over time.

Increasing Participation of Undergraduate Sector in NSF Activities

We believe that organizational as well as programmatic steps are necessary to build such a program. **We urge the Foundation to strengthen its links with undergraduate institutions and programs through a comprehensive effort to involve more faculty from non-doctoral granting institutions in its consultantships, its peer review panels, and its advisory committees. Equally important, NSF should recommend to the White House more well-qualified representatives of undergraduate institutions as candidates for membership on the Presidentially-appointed National Science Board.** Appointments in each of these areas have been drawn overwhelmingly from the research universities, while the wealth of experience in teaching and research at undergraduate institutions has been relatively untapped.

Strengthening NSF Leadership in Science and Engineering Education

We urge NSF to continue to expand its support for research activities at undergraduate institutions across the directorates. It is vital that the skills of quality researchers at undergraduate institutions be utilized as fully as those researchers who have taken positions at research institutions, not only as grant recipients but as members of peer review panels. The Foundation's current $12–13 million investment in quality research at undergraduate institutions has begun to tap this resource: **as expansion occurs in its research budget across the directorates, NSF should allocate an increased share of research funds to investigators in undergraduate institutions and encourage qualified undergraduate faculty to compete for research awards.** Guidelines should be developed based on realistic criteria for different kinds of projects to assure that meaningful opportunities are provided for all kinds of institutions and their faculties to compete for research funds.

Additional dollars invested in research at the undergraduate level have enormous leverage, in terms of strengthening both the capacity of the researchers and the education of future scientists, as well as the value of the research itself. The total amounts needed are often small in comparison to other research investments.

We commend the re-establishment of the Science and Engineering Education Directorate (SEE). Its current initiatives to strengthen pre-college math and science education address the needs of students at the critical years when concepts and attitudes are developed. These activities provide a basis for future expansion to fulfill the responsibilities for supporting science education at all levels as set forth in the original NSF organic act as well as the 1983 Board resolution re-establishing SEE. For example, we believe that the two program initiatives proposed below would appropriately be administered by an expanded SEE Directorate.

In shaping our recommendations for programmatic priorities, we have focused our attention first on two critical areas: tools—instructional equipment and materials, and people—faculty and student needs. In addition, we propose that NSF undertake two crosscutting initiatives designed to provide needed leadership for a national effort to strengthen undergraduate programs: (1) consortial centers of excellence and (2) a program of challenge grants for the improvement of undergraduate science, engineering, and technical education.

Priority One: Undergraduate Instructional Equipment and Materials

In our view, the primary need of undergraduate institutions is instructional scientific equipment and materials. The serious deficiencies in the research laboratories of universities are reasonably well

documented. There the obsolescence of research instrumentation is often in marked contrast with the state-of-the-art equipment of major industrial and national laboratories. As noted in the 1980 AAU report to the Foundation, "The Research Instrumentation Needs of Universities," the equipment deficiencies of undergraduate instructional laboratories, while less well documented, are equally serious. Important progress has been made in recent years in addressing the research equipment needs of universities, but little has been done to address the purely instructional equipment needs of undergraduate institutions and programs.

The category of equipment covers an array of needs, from instruments to keep laboratories current with scientific and technical advances, to scientific periodicals for the library, to site preparation and special facilities to house major equipment, but the most pressing need of undergraduate institutions and programs is for instructional equipment.

The needs are compounded by the rising cost of sophisticated equipment and its rapid obsolescence (instruments which might have had a useful life of 10–15 years may now be outdated after five years due to rapid advances in the disciplines). The needs are common to all undergraduate institutions, including community colleges—and since they enroll about half of all undergraduate students, and many of their graduates go on to baccalaureate programs, the quality of science at these institutions can be an important factor in determining the quality of science at four-year colleges.

Increased NSF leadership and support for undergraduate instructional equipment is urgent because the Foundation is the only federal source for undergraduate science, engineering, and technical programs. These institutions are virtually excluded from competition for research funding by the major mission agencies. **The college science instrumentation program should be substantially expanded. Awards should be made competitively, and institutions should be permitted to apply their expenditures for installation and maintenance as part of their matching contributions. The Foundation should also ensure that institutions provide properly for the continuing maintenance and care of the funded equipment.**

We also urge the SEE Directorate to: (1) expand eligibility for its support for the development and application of instructional technology to improve the quality of teaching in the sciences (Applications of Advanced Technologies); (2) support programs to provide equipment for new and emerging science programs; and (3) support studies and publications that encourage technology transfer among undergraduate institutions. With such NSF encouragement, undergraduate institutions

could exert enormous long-range influence on the quality of science instruction at all levels, from elementary and secondary school though graduate school. The possibility of allocating a portion of Small Business Innovation Research (SBIR) funds for such projects should be explored.

Priority Two: Faculty and Student Needs

It is conceptually impossible to separate teaching and research needs. Research support is the fundamental tool for enhancing the skills of undergraduate scientists and engineers. Institutions cannot attract or keep highly qualified teachers (or keep them qualified) unless there are opportunities for faculty to do research and keep up to date in their fields.

Summer stipends and released time for extended research and faculty renewal and study are two primary and proven mechanisms for faculty renewal. Undergraduate institutions are receiving increasing numbers of requests for released time from their faculty, and college budgets are never adequate for this purpose.

We recommend that NSF expand support for undergraduate research activities across the directorates in addition to the Research at Undergraduate Institutions (RUI) program. At the same time, we recommend that NSF expand support opportunities for undergraduate faculty renewal under the Teacher Enhancement and Informal Science Education program in the SEE Directorate. There is a clear national need to assure a sufficient supply of science teachers and researchers into the next century. To address this policy goal through federal support of graduate assistantships is insufficient because many recipients are lost to industry, and college and university student/faculty ratios cannot justify hiring more of them for the foreseeable future. Therefore faculty research and teaching grants are potentially the most effective federal policy instrument for sustaining adequate supplies of able and committed teachers and researchers in the sciences and engineering.

Student needs, we believe, should be addressed by NSF primarily through support for equipment and faculty needs.

Just as research opportunities are essential for quality teaching, such opportunities for hands-on experience should be made available as widely as possible for outstanding undergraduate students. NSF should encourage undergraduate faculty to develop summer or academic-year research projects that include significant subsidized student participation. Such projects should be judged by separate and appropriate criteria.

NSF already has an outstanding record of commitment to the expansion of opportunities for underrepresented minorities and women

at the graduate level: any new emphasis on undergraduate support should be equally sensitive to this objective. The importance of such efforts was underlined in the NSB report, "Educating Americans for the 21st Century:"

> "By 1995, there will be almost 30 percent fewer college-age students for the workforce. Furthermore, upwards of 40 percent of these young people will be black or Hispanic, the very groups who, for no reason related to inherent ability, are now at the bottom of the educational and economic ladder. Such disparities mean that the Nation continues to suffer from inadequate development and utilization of its human resource potential. The Nation cannot afford such educational casualties."

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The competitive instructional equipment and research programs proposed above, we believe, should form the core of revitalized NSF undergraduate activities. **In addition to these initiatives we make two additional recommendations designed to provide an added dimension to the Foundation's leadership in undergraduate science and engineering education; leverage scarce resources of the Foundation, institutions, and others; and integrate more fully the undergraduate activities of the Foundation with those of undergraduate institutions and programs, faculty, students, and others interested in improving the quality of undergraduate programs.**

First, we urge NSF to carefully develop a program to establish a limited number of consortia as centers of instructional excellence in undergraduate science, engineering, and technical programs. The centers should be strategically located to serve the various geographic regions of the country and to build on existing institutional strengths in undergraduate instructional programs.

Second, we propose a program of challenge grants, modeled after the successful NEH challenge grant program, to provide undergraduate institutions and their patrons with opportunities to examine institutional instructional objectives, articulate related needs, and develop realistic plans for strengthening the quality of their science, engineering, and technology programs.

Consortial Centers of Excellence

We believe that opportunities exist for major advances in cooperative efforts to strengthen science education on a regional basis. Such opportunities could be realized though NSF leadership in establishing a program of consortial centers of excellence.

The mission of these centers should be to bring together outstanding teachers, researchers, and students from a variety of involved institutions from high school through graduate school and corporate research programs, and through such vertical networking to devise ways to better meet regional needs. The potential for pooling science resources and facilities and for enhancing institutional strengths in research and teaching are two areas that should be explored. Such centers also could develop joint projects for cooperation with the elementary and secondary schools through workshops, summer institutes, round tables, and other programs for teacher training and faculty exchange; curriculum development; and dissemination of materials for training, retraining, and in-service development in mathematics, science, computer science, and technical occupation fields; expansion of research opportunities for faculty and students, including cooperative projects with industry; and development of technical programs in emerging sciences.

Successful consortial arrangements are challenging to develop. They require careful thought, planning, and time to develop fruitfully. Seed money is an early essential ingredient. NSF could leverage limited resources, and prepare for more fully developed efforts in future years, by first soliciting proposals for a limited number of relatively small planning grants to be used to develop competitive proposals. Planning grants will stimulate broader national and regional interest in undergraduate concerns that will benefit all competing institutions. In the second round the Foundation could select a small number of proposals for funding as pilot projects for a period of at least five years, with increasing local matching and built-in evaluation required in subsequent years. If the pilot projects succeed, proposals could be solicited to establish additional consortial centers of excellence in other regions of the country.

NSF should emphasize the need to involve different types of institutions in the proposed consortia, including high schools and technical colleges. Most consortia tend to be integrated horizontally among similar institutions rather than vertically to involve a mix of institutional types.

Challenge Grants for Improvement of Undergraduate Science and Engineering Education

We strongly urge NSF to establish a Challenge Grant program for Improvement of Undergraduate Science and Engineering Education, similar to the $20 million program conducted by the National Endowment for the Humanities. Three-year challenge grants with significant

matching provide exceptional opportunities for leveraging relatively small, short-term federal expenditures into a large-scale effort at institutional advancement.

Challenge grants will foster broad improvements in the quality and effectiveness of undergraduate science education. They will encourage undergraduate institutions throughout the country to further identify and articulate their most pressing needs in science education. Awards should be based on detailed plans for a coordinated set of activities to strengthen an institution's total science effort, including faculty development, student needs, and important improvements in equipment and facilities. As with the NEH program, NSF will find that it will stimulate significant additional private support from alumni, corporations, and other prospective donors.

A Goal for Future Growth

We believe that the priorities outlined above should guide the Foundation in a sustained effort to achieve realistic growth of its leadership in strengthening undergraduate science and engineering education. **As an immediate goal we recommend that NSF seek to expand its existing research and education activities in these areas across the directorates by an additional $100 million. Of this sum sixty percent should be allocated for instructional equipment; twenty percent for support of faculty research and teaching; ten percent for consortial centers of excellence; and ten percent for Challenge Grants for science education and improvement.**

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These four recommendations represent a strong consensus of the undergraduate science community. We believe that their implementation would greatly assist the Foundation in pursuit of its statutory mission "... to recommend and encourage ... national policies for the promotion of ... education in the sciences ... and to initiate and support ... programs to strengthen science education at all levels."

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